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DEVELOPMENT OF EMPLOYMENT SUB-CENTRES IN THE CITY OF AHMEDABAD, INDIA

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Abstract

This paper describes how employment sub-centres can be identified applying geo-spatial modelling techniques in the context of metropolitan areas in India, and how the development of these employment centres can be linked to levels of accessibility to labour, access to transport infrastructure as well as land use mix and land use diversity. For the city of Ahmedabad, employment sub-centres are identified for the year 2010, while the progression of employment in retail, commercial and industrial sectors in each of these centres is studied for the period 1980 to 2010. Definite signs of sprawl type development and polarisation reversal are observed, including the emergence of new employment sub-centres across the urban area, and the rapid growth of centres further away from the Central Business District. Retail and commercial sectors have grown exponentially, whereas industrial and manufacturing sector growth is stagnant. This development is mixed and heterogeneous, with the growth of the retail and the commercial sectors found to have a significant and positive relation with access to labour and transport infrastructure. These identified patterns of development provide important information to urban planners enabling them to make informed decision, *e.g.* in locating future employment activities, identifying future Transit Oriented Development nodes, *etc.*

Keywords:

GIS
Employment Sub-Centres
Accessibility
Land use
Spatial Correlation

1. INTRODUCTION

Rapid urbanization and urban growth are a recognized fact in India (MOUD, 2011). Studies have noted changing urban and metropolitan structure, spatial expansion of built up area, the dispersal of economic activities and emergence of polycentric structures (Mahadevia, 2001, Roy, 2009, Chattopadhyay, Munshi, 2013). What is not very clear is the precise definition and the determinants of growth in these urban centres (employment sub-centres). Urban planners prepare statutory urban development plans to accommodate urban growth, provide housing and other infrastructure to support urban growth and ensure sustained growth of cities. However, the planning methods and tools used to prepare statutory urban development plans in India have been criticized as being ineffective (Munshi, 2013, Munshi et al., 2014b), while regulators have only a partial control on development resulting in a large portion of land use development to be of a laissez-faire type (Munshi et al., 2014b, Ballaney and Patel, 2008, Ilhamdaniah et al., 2005). One can assume that the development of employment sub-centres outside the central core area is more organic development and less planned.

This laissez-faire type of distribution of land uses and emergence of employment sub-centres outside the city core itself can provide key inputs as to how and where land uses develop and can serve as precursors on how to go about planning cities. With the recent focus on developing nodes around transit lines and stops, research on how activities cluster can provide key inputs to urban planners. Typically, firms and establishments cluster at central locations (Hotelling, 1929, Christaller and Baskin, 1966) to gain benefits resulting from production optimization, innovation and business opportunities (Porter, 2000), typically termed Central Business Districts (CBD). Because demand to locate centrally is high, the cost of locating centrally are also high. By relocating away from the Central Business District (CBD), firms can typically

optimize their cost of production (Fujita et al., 2001); also referred to as polarization reversal (Richardson, 1980). As such, modern metropolitan areas are not always monocentric and may have a number of sub-centres that rival the CBD location. In conventional literature, this phenomenon is already widely discussed (Kloosterman and Lambregts, 2001, Anas et al., 1998, Meijers, 2005, Hall and Pain, 2006). Development of employment sub-centres in most cities reflects the rise in service economy and also indicates increased autonomy of sub-areas within the city from the CBD area (Romein et al., 2009). Linkages with transport and customer/labour/goods leading to, for example, commuter flows, are important drivers of polycentric development (Giuliano et al., 2012). Moreover, as stated there can be a tendency to locate centrally, so distance from the city centre can influence locations where economic activity clusters' develop.

Indian cities are different from cities in the Western Countries, where the above-mentioned theories were developed and tested. As cited in the case of Ahmedabad and Rajkot (Munshi et al., 2014b, Munshi et al., 2004, Munshi et al., 2014a), in Indian cities, activities show a tendency to locate close to the centre of the town. Accessibility to other activities (including residential) has a positive influence on activity location, indicating a tendency for activities to cluster and locate in proximity to each other. Cities are dense and heterogeneous; they are also likely to be less service-oriented, while affordability of transport costs to most residents is also limited. This makes it interesting to explore the formation of employment sub-centres and attribute reasons to it, which is the main objective of this paper. Therefore, in this research, the emergence of employment sub centres outside the Central Business District (CBD) is identified. The growth of retail, office and industrial floor space within these identified centres is studied with respect to their proximity to number of resident workers, distance from city centre, and the configuration of the transport network and land use. The case study city of

Ahmedabad is located in the state of Gujarat in western India (figure 1). Ahmedabad is considered a typical city that is classified in the second tier of cities in India as it is confronted with rapid urban growth and related urban problems typical to most Indian cities.

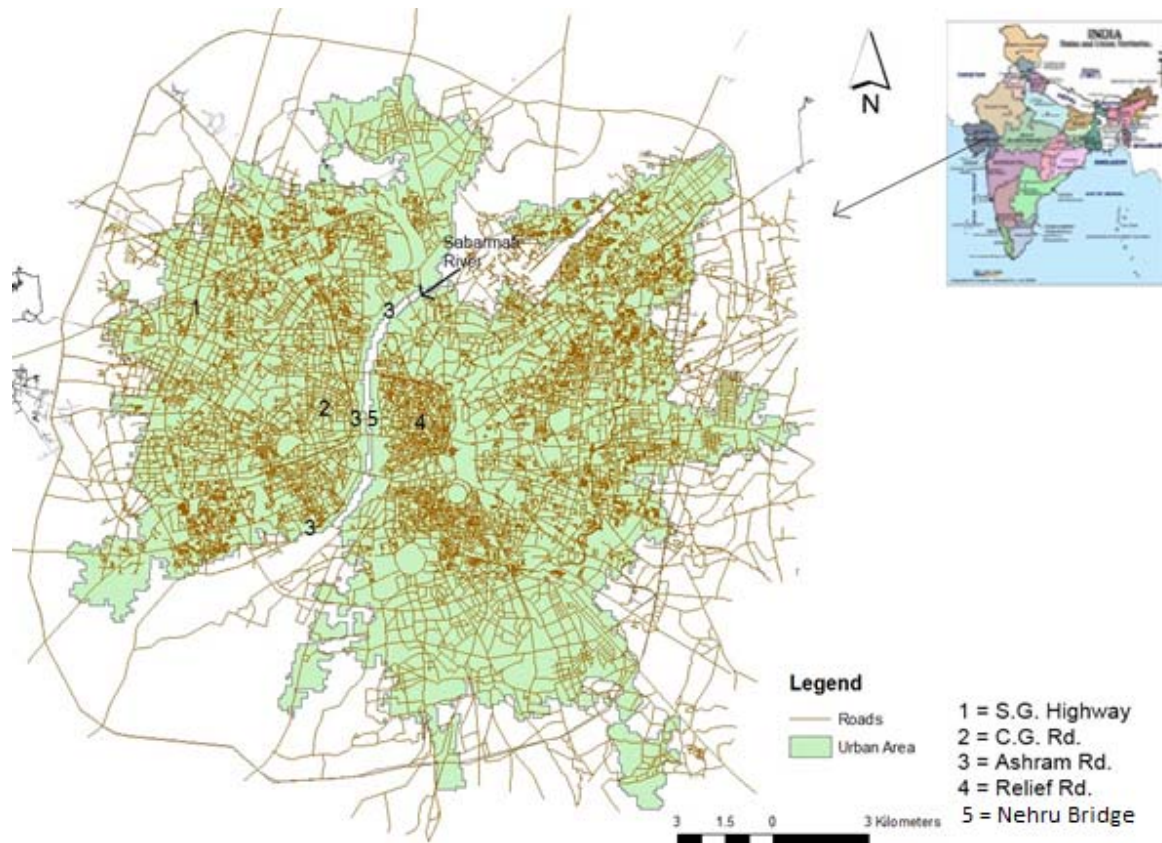


Figure 1: Ahmedabad city location

This paper is further organised in two main sections followed by conclusion and discussion. In the next sections, the concepts and methods for identifying sub-centres using GIS are discussed. Following, the employment sub-centres for Ahmedabad are identified and characterized, and a change in topology of employment and its relation with access to labour, distance from city and configuration of transport network and land use is discussed. Finally, the last section draws conclusions and presents recommendations for further research.

2. RESEARCH APPROACH, METHODOLOGY, AND DATA

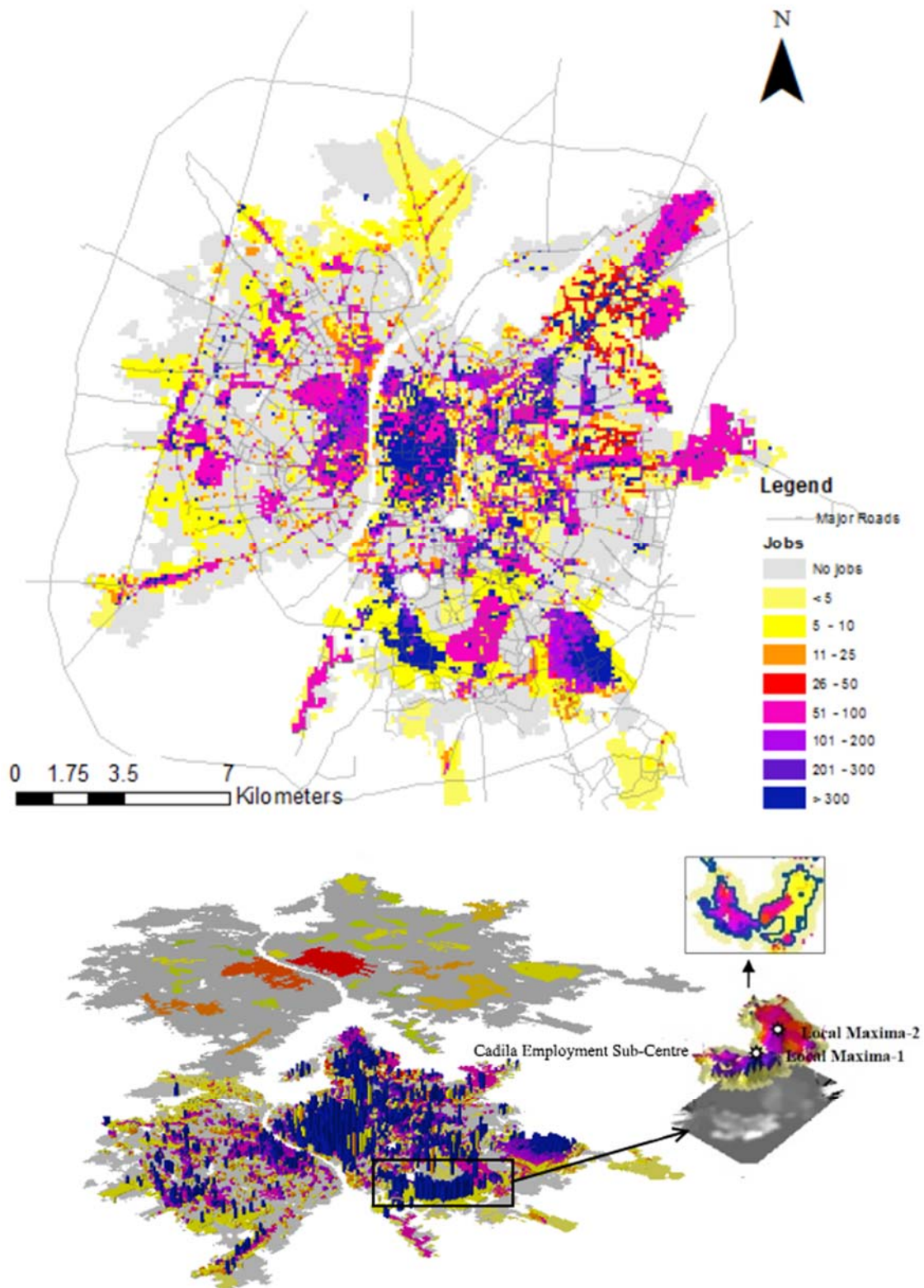
Giuliano and Small (1991, 1999) and in other empirical research (Anderson and Bogart, 2001, Bogart and Ferry, 1999, Small and Song, 1994, Shearmur and Coffey, 2002, McMillen and McDonald, 1997) identify employment sub-centres as locations that form a continuous cluster with a cut-off for employment density and a minimum total employment. The cut-off point of gross employment density used is 10 jobs per acre (25 Jobs per hectare) in Giuliano and Small (1991), while other studies have used slightly different cut-off densities, for example, Song (1994) use cut-off job density as 37 jobs per hectare and Anderson and Bogart (2001) use cut-off job density as 20 jobs per hectare. The total minimum employment in the identified continuous cluster between 5,000-10,000 jobs (Giuliano and Small, 1991) and 35,000 in Small and Song (1994). Shearmur and Coffey (2002) also used employment to residents ratio (greater than one) to identify the continuous clusters of employment. Other methods use a two stage non-parametric approach to identifying employment clusters (McMillen and Smith, 2003, McMillen, 2001, Redfearn, 2007). In Redfearn (2007) a local weighted regression curve (Loess curve) is used to generate an employment density surface, from which employment sub-centres are identified. An employment sub-centre is identified as a location having substantially higher employment density compared to its neighbouring area. A similar approach includes the estimation of spline functions (Craig and Ng, 2001, Muniz et al., 2003), which is a non-parametric specification of a density function, an approach that is similar to the boundary definition procedure used in Redfearn (2007). McMillen (2001) identifies sub-centres using the properties of a contiguity matrix. This method uses the residues of an econometric estimation of the density function (parametric or non-parametric). The residues that are statistically diverse from zero are considered as so-called candidate sub-centres.

In this study employment sub-centres are identified using a 100 m equal side grid to quantify the various data. Data on the distribution of commercial, retail, industrial and residential floor space were available from Munshi (2013). The data on the total workers in different categories are available from the census (2001 and 2011) and are used to disaggregate jobs to each grid cell using proportion of the area under each activity in the cell. Subsequently, the following steps were followed to identify employment sub-centres:

1. A topological surface of employment densities is created;
2. From the employment density surface, all local maxima are identified and considered as candidate employment centres;
3. Contiguous grid cells around the local maxima that have more than a minimum qualifying threshold of 10 jobs/acre are selected to form a cluster;
4. For each cluster, all grid cells in the clusters plus other grid cells in the neighbourhood (equal to the number of grid cells in the employment sub-centre) are selected;
5. A non-parametric Loess surface is created using the methods described in Redfearn (2007).
6. For the Loess surface, the following definition of an employment sub-centre by Redfearn (2007) has been used: all the contiguous cells that have values higher than the mean minus half standard deviation (of all the Loess surface values) are selected and considered as an employment sub-centre within the city.

As an example, in figure 2, a representation of the methods used to identify the employment sub-centre no. 10 is shown. Locations with values higher than 10 jobs/acre are identified as potential areas for employment sub-centre in step 1, one of these centres being Cadilla area. These locations, as identified in step 1, are then deducted from the rest of the city area. In this remaining surface, the non-parametric density value of 93 (mean (39) + half standard deviation

(108)) is used as the cut-off value to identify the location of the sub-centre. The resultant area is finally identified as the employment sub-centre no 10, which was confirmed by local knowledge of the area. This procedure is used to identify 28 employment sub-centres next to the existing CBD city centre. In figure 3, these centres are also ranked in the order of employment numbers. The river Sabarmati appears to act as a barrier to the traditional CBD (1 in figure 3) for the residents living west to the river. This has led to the creation of a large employment sub-centre in the western part of city mirroring the traditional CBD. Other smaller employment sub-centres have also emerged on both sides of the river.



Digital Elevation Surface of Employment Density and Identification of Cadilla Employment Sub-Centre

Figure 2: Topology of jobs and identification of employment sub-centres in Ahmedabad

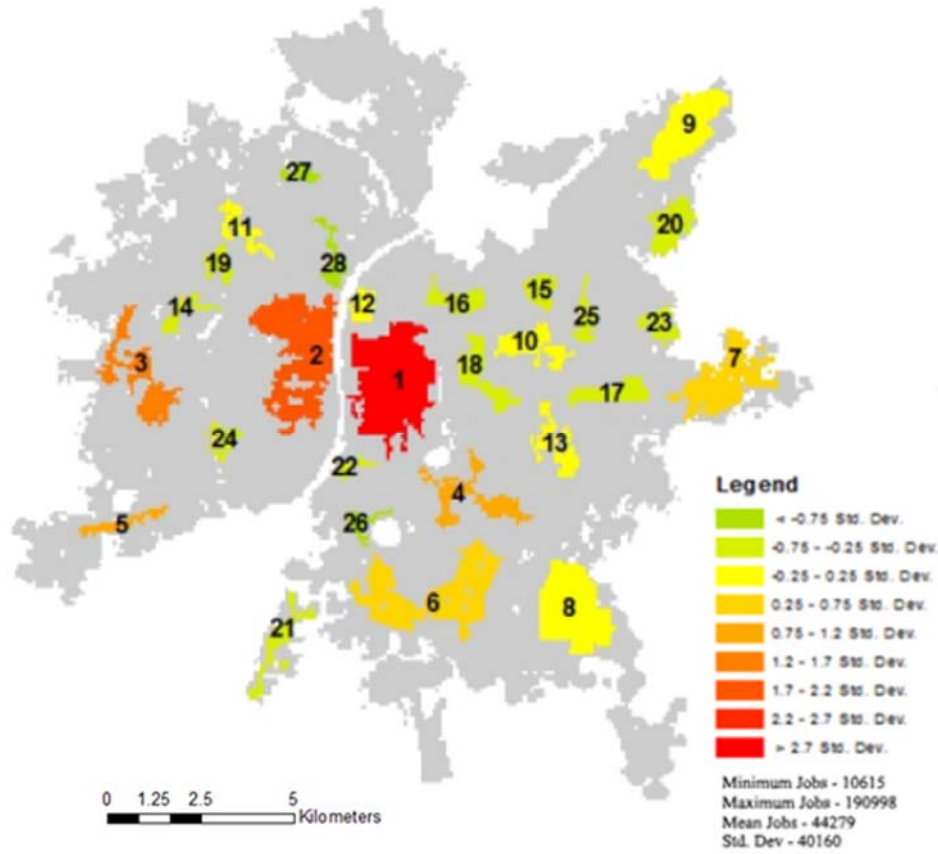


Figure 3: Identified employment sub-centres

Accessibility can be defined as the ‘ease of reaching opportunities’, and is concerned with increasing the ability with which people in different locations, and with the differing in availability of transport, can reach different services or opportunities, such as employment, shopping and leisure (Stantchev & Merat 2010). The development potential of a location (and thereby land prices) has a strong correlation with accessibility (partly a function of transport mobility) (Giuliano et al., 2012). The transport cost, representing individual's reluctance to travel in many ways effects spread and clustering of economic activities (Brotchie, 1984). For the development of economic activities, they need access to transport networks, access to transport nodes, access to labour force. The accessibility to labour is computed as access to individuals (residential workers) from a given location. The data on numbers of residential

workers was available from Census data 2001 and 2011, and was available at the census ward level, disaggregated to grids of 100 m using residential building floor space as a distribution function. The accessibility to labour is operationalized as in equation 1.

$$a_i = \frac{1}{\sum_{j=1}^n LF(d_{ij})} \dots \dots \dots \text{Equation 1}$$

where a_i (used as the balancing factor in the gravity model) is a measure of accessibility at the employment sub-centre i to the availability of labour L , $F(d_{ij})$ is a function of d_{ij} for which in this case the exponential function is used. The variable d_{ij} is the distance between i and j . Accessibility values are accordingly normalized between 0 to 100.

Data on the road network was sourced from Munshi (2003) and updated using Cartosat image data from 2007 and by using Google Maps data for 2011. To compute accessibility to roads and public transport a Kernel density function is used, which is based on Tracy et al. (2011). Access to major roads is computed using Kernel density function, using road width as the population field¹ and accessibility to public transport computed as kernel density of public transport stops, using the number of routes as population field². Distance from the city centre provide inputs on how proximity to the centre influences employment growth, this is computed as network distance from the centre fo Nehru Bridge to the centre of employment sub-centre.

Land use mix and diversity can, first of all, indicate whether the employment sub-centre emerge as exclusive employment zones, and second, provide inputs to the development potential of employment if the location are mixed with residential and other land uses. The land use mix

¹ As Kernels are drawn for each line (road section), the function used in this study accounts for both road width and road length

² As Kernel is drawn from each bus stop, the function used in this study accounts for both number of stop and number of bus routes.

and diversity is quantified by adapting land use extropy and land use diverstiy indicators from (Cervero and Kockelman, 1997). Entropy index and dissimilarity index are quantified as shown in equation 2 and equation 3.

$$\text{Entropy} = E_i = \sum_j \frac{F_j \times \ln(F_j)}{\ln(J)} \dots\dots\dots \text{Equation 2}$$

where J is the number of land use classes (five land use classes have been considered in this study: residential, commercial, institutional, industrial and recreational), F_j is the proportion of the total developed floor space area under the j th land use type. An area within a radius of 800 m. (8 grid cells) is considered as the neighbourhood.

$$\text{Dissimilarity Index} = \sum_j^k \sum_i^8 (\frac{X_i}{8}) / K \dots\dots\dots \text{Equation 3}$$

where K is number of actively developed floor space in a grid cell and $X_i = 1$ if central active floor space use type differs from that of neighbouring grid cell.

The relation between the growth of employment within the identified employment centres and accessibility to labour, accessibility to transport, land use mixing and distance from city centre is studied using the spatial autocorrelation *Moran's I* statistic (Anselin et al., 2006). LISA significance maps (Anselin et al., 2006) are also used, as these maps depict the locations with significant Local Moran statistics and classify those locations by type of association.

3. RESULTS

The inventory of identified employment sub-centres is studied for growth in the number of jobs for four time periods: 1980, 1990, 2000, 2010. Table 1 shows the distribution of jobs and their growth in the last three decades. Age of the building³ is used to compute the values in the table. It is found that the primacy of the CBD (employment centre 1) has steadily decreased over the

³ Using age of the building as a proxy for age of the activity at the location does not account for change in the activity, that is, it does not indicate the age of the building and if it was used previously for some other purpose.

But given the data situation in India, this was the best proxy data that could be used for the purpose.

last three decades. In 1980 close to a quarter of the total employed in Ahmedabad worked in the CBD area, other employment centres were either industrial areas or the area adjacent to the city centre on the other side of the river. The number of employment sub-centres with jobs more than 10,000 has also increase from nine (this excludes the CBD) in 1980 to 13 in 1990, to 24 in 2000 and 27 in 2010. The total employment contained within identified employment sub-centres was 83 percent in 1980, while it has reduced to 69 percent in 2010 despite increase in the number of employment sub-centres. The development of many employment sub-centres with a small number of jobs and the reduction in overall employment in these sub-centres indicates sprawl type of development. The urban form in the 1980, represents a city, where activities has just started to sprawl beyond the CBD area, mainly under the pressure of rural-urban migration and rapid population growth. In the 1990's the Indian economy was liberalized, during this period the growth of jobs in cities like Ahmedabad outpaced the formal land use formation. There was rampant conversion of land use from residential land use areas to retail and commercial uses and the development of spontaneous retail and commercial areas in peripheral areas leading to a spur in the number of employment centres from 13 to 24. In the years between 2000 and 2010 employment consolidated further in peripheral areas and also in the infill areas.

Table 1: Employment sub-centre and growth in number of jobs

Emploment Sub Centre	1980		1990		2000		2010	
	Jobs	% of Total Jobs	Jobs	% of Total Jobs	Jobs	% of Total Jobs	Jobs	% of Total Jobs
1	83200	23	95776	17	148513	12	190998	11
2	23436	7	33490	6	92093	8	123277	7
3	1151	0	5148	1	84697	7	109879	6
4	29782	8	43467	8	67423	5	86094	5
5	1185	0	2335	0	46384	4	77453	4
6	29453	8	41966	7	55004	4	65548	4
7	13532	4	20386	4	41285	3	55303	3
8	11684	3	23181	4	31185	3	40850	2
9	6645	2	11651	2	27312	2	39151	2
10	6345	2	15473	3	29456	2	38993	2
11	2062	1	5194	1	26373	2	38676	2
12	23022	6	26499	5	32529	3	36408	2
13	10910	3	15806	3	30365	2	34839	2
14	1437	0	3647	1	27805	2	32288	2
15	10015	3	16456	3	24844	2	28450	2
16	3838	1	5483	1	20252	2	27534	2
17	5961	2	15367	3	24265	2	27379	2
18	11647	3	16546	3	22782	2	26393	1
19	3790	1	3807	1	16581	1	23913	1
20	9767	3	11553	2	17590	1	20921	1
21	1130	0	8165	1	15170	1	17974	1
22	7380	2	9991	2	15980	1	17155	1
23	1742	0	3586	1	14077	1	16186	1
24	729	0	2313	0	11001	1	14878	1
25	2445	1	4230	1	11716	1	14672	1
26	4298	1	6958	1	9126	1	12777	1
27	833	0	1350	0	6692	1	11218	1
28	1813	1	2893	1	6995	1	10615	1
Other areas	46207	13	113179	20	270063	22	531352	30

Source: Study results

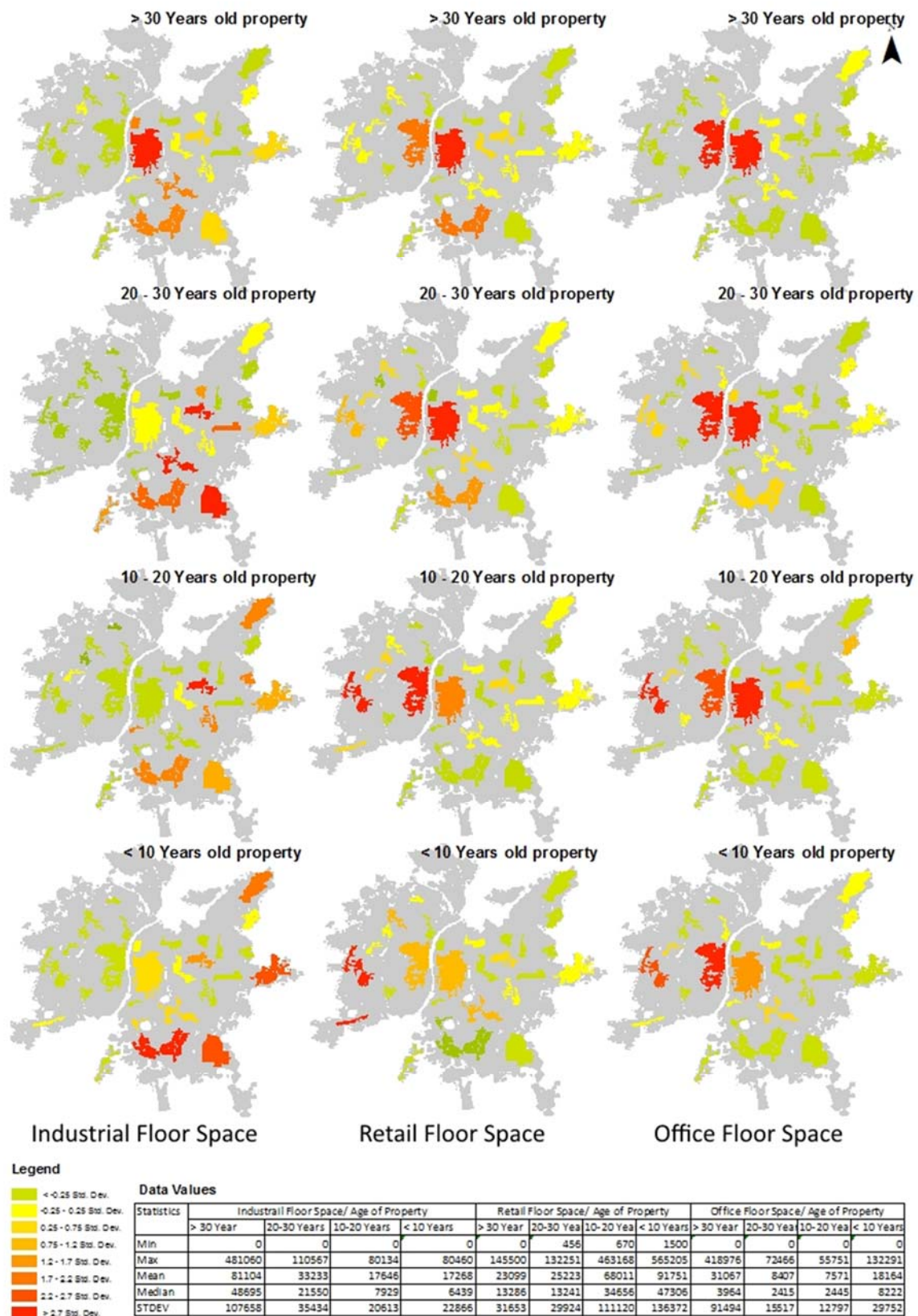


Figure 4: Employment sub-centre and development of industrial, retail and office floor space

It is also obvious that reverse polarization is taking place and development is moving towards the peripheral locations. The spatial distribution and growth of the retail, commercial and industrial jobs in the past four decades within the identified employment sub-centres is shown in Figure 4. Industrial floor space includes small-scale factory production, printing industry metal and all other allied activities that use floor space for production purpose including in the food industry. Overall, the industrial sector has not grown as fast as other sectors when we look at both the employment number (table 1) and development of floor space. There are still a significant number of industrial establishment that are more than 30 years old, which mainly locate in and around the walled city area in the in select industrial zones in the eastern part of the city. The development has progressively moved towards the periphery over the years, with most of the recent industrial development concentrated along the four industrial centres towards the eastern periphery of the city. Retail floor space has grown exponentially in the last 20 years. The CG road (employment sub-centre 2) and SG highway (employment sub-centre 3) (See figure 1 and figure 3) are where most retail development has taken place, and where the presence of good road infrastructure in these area has clearly contributed to the emergence of large shopping complexes in these areas. Thus, a majority of retail floor space is concentrated with three major centres but statistical values presented in figure 4 suggest, as one can expect, retail land use well distributed among all centres. In addition to the formal retail, which is captured in the numbers presented in figure 4 and table 1, a significant proportion of retail activities are informal development and are street side activities these have come along transport nodes and major node across the city. This study does not incorporate these developments, but these activities can be expected to pattern the formal land use development. Office floor space more or less patterns the retail floor space development and large number

recent floor space development took place in western part of the town mainly the SG highway city centre.

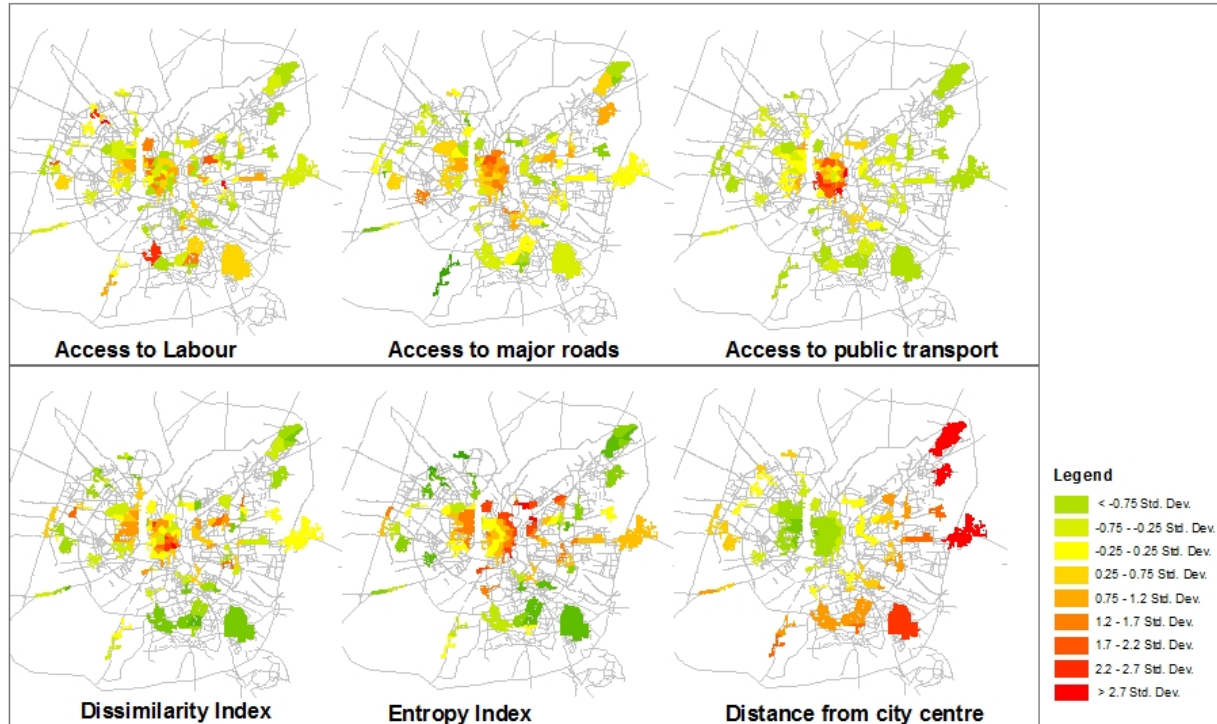


Figure 5: Access to labour, access to transport, built form indicators

Table 2: Descriptive statistics of access to labour, access to transport, built form indicators

Indicator	Minimum	Maximum	Mean	Std. Deviation
Access to labour	1	100	8	12
Access to major roads	878	3574	2457	541
Access to public transport	3	646	137	124
Dissimilarity Index	0.01	0.92	0.39	0.22
Entropy Index	0.12	0.83	0.45	0.18
Distance from city centre	1.4	15.2	5.6	3.1

Source: Study results

Descriptive statistics of quantified indicators are presented in figure 5 and table 2. Clearly, a pattern does emerge. Central portions as expected have better access to labour, transport and also have mixed and diverse land use. Most public transport bus routes (only AMTS bus routes considered and BRTS only started operation in 2009) are also located in and around the wall city area.



Figure 6: Spatial co-relation between growth of retail, commerce and industrial activities and access to labour, transport, and land use indicators.

The spatial co-relation of the land use growth with the indicators described in section 2 are now studied by computing the *Moran's I* value as described in (Munshi, 2016), the LISA cluster maps and Moran's I spatial auto correlation values are presented in figure 5. Positive Moran's I value indicates positive relation likewise negative value indicates a negative relation. LISA significance maps are also indicate the locations where the significance of these relations are high. The Moran's I values for access to labour is positive and comparatively higher for retail development and commercial development and the significance of the relation is very high in several portions of the town, mainly along the western periphery, and employment sub-centres abutting the CBD. The new areas where activities have located in the past 30 years are location where residential development has taken place as well as location where space for development

is available. The Moran's I value of the relation between retail, office and industrial development with distance to the centre of the town also further explains this, positive and high Moran's I value and high level of significance indicates that activities especially retail and commercial activities have located away from city centre a clear indication of polarization reversal. New activities have developed mostly in areas where land use is mixed and diverse. The Dissimilarity index appears to have a strong relation to activity development within employment sub-centres in central parts of the town, where as entropy index representing land use balance has a very strong relation with activity development in the peripheral areas of the town. Access to roads and public transport as expected have strong and significant relation with development of all employment generating activities especially retail and commercial development. From figure 6, one can say that the new activities develop at locations where accessibility to roads and public transport is good, and where the land use is mixed and diverse. Even the industrial areas are not exclusive nodes, retail and residential land use have also been found in the industrial area. Lastly, population density has little relation with the development of activities, probably because of existing development control regulation, which restrict locations where new activities can develop and the amount of activities that can come up at a particular location.

4. CONCLUSION AND DISCUSSION

The purpose of this research was to identify employment sub-centres in the city of Ahmedabad and study the possible factors that supported the development of these employment sub-centres. This is done to gain knowledge, which can be used to support urban planning decisions in Ahmedabad and other similar cities.

The research showed that it is possible to establish suitable methods for identifying sub-centres in the context like India that has rampant unplanned growth. It is important to identify employment sub-centres, identification of existing nodes itself can help urban and transport planners to align services, for example, public transport service with these nodes. By using a cut-off employment density of 10 jobs/acre, areas that have significant employment are identified, and from these employment sub-centres could be identified by using the non-parametric method. Identification of employment also allowed analysis of the pattern of their growth and employment activities in the city. A distinct pattern of employment sub-centre formation can be observed. From the analysis of topology of employment and how employment sectors have grown, two types of agglomerations are apparent: one related to trade and commerce and the other to industry. Incidentally, in the case of Ahmedabad, these are separated by the river that divides the city in two halves. Industries are located in the eastern part and trade, commerce and the banking sector are mostly located in the west. Accessibility has played a significant role in the formation of employment sub-centres. There has been a tendency to locate away from the CBD, that is, new firms have located at locations where there is good supply of road space and access to labour. There is also a strong co-relation with land use mix; therefore, these employment centres are not exclusive retail or commercial development they generally develop as mixed land use along with other land uses like residential land use. The emerging patterns, spatial relations and other statistics presented in this paper will help planners understand the spatial interaction between activity locations. The outputs of this paper also position well in the recent debate on transit-oriented development and CBD planning. The results provided enough information for planner to make indicative judgements, of course, in the final decision-making they might have to consider several other factors social, economic and regulatory factors also.

In this research informal activities and their location have not been captured which can be significant number of jobs. If data is available on these activities, information derived can supplement the work from this research. In Ahmedabad, the BRTS system has partially changed how individual access activities, this will further change with introduction of the newly proposed Metro system which set up well for a follow up research on how public transport and its use affects employment sub-centre formation and growth.

The research didn't analyse the effect of polycentric development in Ahmedabad on mode choice distances individual travel and also on spread of population. Based on past empirical work it can be assumed, however, that the spread out, heterogeneous and dense development pattern of employment sub-centres in Ahmedabad should encourage higher use of non-motorized modes and public transport (if available). Formation of poly-centric node should also have encouraged decentralization of population towards the peripheral areas reducing/stabilizing the density in the central areas of the city. However, these are important possible ramifications, which need further research.

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